Stream Shade Monitoring on the Klamath National Forest, 2010

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ABSTRACT

Stream shade was estimated for perennial streams on the Klamath National Forest using the Shade-a-lator model with inputs for vegetation derived from remote sensing data. Air photo interpretation was used to verify the remote sensing data, and to identify reaches where stream shade has been reduced by human activities. The amount of shade loss due to human activities was estimated by comparing the modeled shade in altered reaches with near-by stream reaches that lack human disturbance. A total of 44 out of 87 watersheds on the Forest have human-caused shade loss. Of these, 12 watersheds have a shade reduction of less than 0.1% of the watershed average shade. The maximum shade loss due to human activities is 8.2% of the watershed average shade. The average shade of all watersheds in the Salmon and Scott Rivers is attaining the TMDL targets even though some individual watersheds are not meeting the site-potential shade.

INTRODUCTION

The North Coast Regional Water Quality Control Board requires the Klamath National Forest to monitor stream shade as a condition of the Klamath, Salmon, Scott, and Shasta River Total Maximum Daily Loads (TMDLs). Monitoring requirements for Forest Service lands are outlined in two Memorandums of Understanding (NCRWQCB 2009a,b), and a Waiver of Waste Discharge Requirements (NCRWQCB 2010b). The monitoring methods have been approved in a Quality Assurance Project Plan (QAPP 2010). This report presents the results of the shade monitoring conducted under the QAPP in 2010.

COMPLIANCE CRITERIA

The load allocations for stream temperature in the Klamath, Scott, Salmon, and Shasta TMDLs are expressed as site potential effective shade, which is the naturally occurring stream shade in the absence of human disturbance. Site potential effective shade is defined in the Klamath TMDL as:

"the shade provided by topography and full potential vegetation conditions at a site, with an allowance for natural disturbances such as floods, wind throw, disease, landslides, and fire".

The load allocation in the Salmon TMDL requires an average shade of 69.7% for all streams in the watershed. The Scott TMDL uses a distribution of percent shade by the length of all streams in the watershed.

METHODS

Stream shade was measured using remote sensing at inventory points located every 100 meters along all perennial streams on the Klamath National Forest GIS streams layer. Streams on private lands, along the Klamath River, and streams draining to the Butte Valley were excluded. The final network of inventory points includes a total of 41,139 points representing 4,113,900 meters of stream channels.

Stream shade at each inventory point is estimated using the shade-a-lator model developed by the Oregon Department of Environmental Quality (Boyd and Kasper, 2003). The Shade-a-lator is a module of the Heat Source Model that was used by the North Coast Regional Water Board in developing the TMDL targets for stream shade and temperature. The Shade-a-lator predicts stream shade based on the physical attributes along a stream. Some of these attributes remain fixed for each point (Table 1), while the vegetation attributes are variable (tree height, density, and overhang). Changing the value of the vegetation attributes is the primary means of measuring the effects of management on stream shade. Shade-a-lator results are expressed as effective shade, which is a measure of the percentage of total daily direct beam solar radiation that is blocked by vegetation or topography before reaching the stream surface.

The aspect and bankfull width for each point are derived from modeled streams created by a Digital Elevation Model (DEM). Bankfull width categories were assigned based on drainage area as shown in Table 1. Errors can occur in the aspect and width values because the DEM-derived streams are not spatially consistent with the GIS streams layer and the shade points are not always closest to the appropriate DEM stream segment. Width and aspect were manually checked for each of the shade points and any identified errors were corrected. Channel incision and topographic shade were set at 0 due to a lack of resolution in the DEM.

Table 1. Shade-a-lator attributes that are non-variable for each site

Attribute	Assumptions and Values Used
Lat/Long	All points are assigned a latitude of 41.5 degrees north, longitude of 123 degrees west which is approximately the center of the Klamath NF
Riparian zone width	4.6 meters
Elevation	450 meters (approximate median for the Forest)
Date	June 21 (summer solstice)
Aspect	north, south, east, or west, NE, SE, SW, or NE
Bankfull width	Drainage area: less than 5 square kilometers = 2, 5 to 25 sq km = 4, 25 to 125 sq km = 8, 125 to 625 sq km = 16, greater than 625 sq km = 32.
Wetted width	½ of the bankfull width (“1”, “2”, “4”, “8”, and “16” respectively) and wetted depth proportional to bankfull width (0.1, 0.2, 0.4, 0.8 and 1.6 meters deep respectively)

Vegetation Attributes for Existing Conditions

The existing stream shade at each inventory point is estimated using the Shade-a-lator model with vegetation input from the Forest Service EVEG layer. The EVEG layer is a GIS layer containing polygons of existing vegetation derived from Landsat imagery, developed by the U.S. Forest Service Remote Sensing Lab (USFS 2009). EVEG includes information such as vegetation type (species), tree and shrub cover (crown density in 10% increments), tree size in diameter classes, and other data.

The tree diameter and canopy cover from EVEG is converted to the tree height and density classes used in the Shade-a-lator model as shown in Table 2. There were relatively few points in the density categories between 10 and 50% tree cover so these were lumped into a single category, as were the 80-90% and 90-100% tree cover categories. Also, shrubs were lumped into "dense" (greater than 80% shrub cover), "medium" (between 50 and 70% shrub cover) and "open" (between 10 and 50% shrub cover) shrub categories. Other vegetation with less than 10% cover was called either "Barren" (some tree or shrub cover but less than 10%), "Non-Forest" (non-wet meadow grasslands) or "Wet Meadow".

Table 2. Conversion of the EVEG categories for tree diameter and canopy cover to the height and density classes used in the shade-a-lator model.

Code	Diameter / Canopy Cover Categories from EVEG	Height (m)	Density (%)	OH (m)
1	large 10-50% tree cover	40.0	30%	2.0
2	large 50-60% tree cover	40.0	55%	2.0
3	large 60-70% tree cover	40.0	65%	2.0
4	large 70-80% tree cover	40.0	75%	2.0
5	large 80-100% tree cover	40.0	90%	2.0
6	medium 10-50% tree cover	25.0	30%	2.0
7	medium 50-60% tree cover	25.0	55%	2.0
8	medium 60-70% tree cover	25.0	65%	2.0
9	medium 70-80% tree cover	25.0	75%	2.0
10	medium 80-100% tree cover	25.0	90%	2.0
11	poles 10-50% tree cover	10.0	30%	2.0
12	poles 50-60% tree cover	10.0	55%	2.0
13	poles 60-70% tree cover	10.0	65%	2.0
14	poles 70-80% tree cover	10.0	75%	2.0
15	poles 80-100% tree cover	10.0	90%	2.0
16	seed-sap 10-50% tree cover	3.0	30%	1.0
17	seed-sap 50-60% tree cover	3.0	55%	1.0
18	seed-sap 60-70% tree cover	3.0	65%	1.0
19	seed-sap 70-80% tree cover	3.0	75%	1.0
20	seed-sap 80-100% tree cover	3.0	90%	1.0
21	Dense Shrubs	2.0	90%	1.0
22	Medium Shrubs	2.0	65%	1.0
23	Open Shrubs	2.0	30%	1.0
24	Barren	10.0	5%	1.0
25	Non-Forest	1.0	50%	0.0
26	Wet Meadow	1.0	90%	0.0

The EVEG diameter classes (inches DBH) were converted to tree height categories (meters) as follows: Medium and large to giant sized trees > 20 inches = 40 meters; Small trees 10 to 20 inches = 25 meters; Poles 5 to 10 inches = 10 meters,; and "seed-sap" = 3 meters. Overhang values were assigned based on tree size. All large, medium, and pole-sized categories were assigned an overhang value of 2.0. Smaller tree and shrub categories were assigned an overhang value of 1.0, and the grass categories were assigned an overhang value of 0.0.

A point-on-polygon overlay was performed to attach the EVEG information to each shade inventory point. Results of the overlay were visually examined over 2008 or 2009 NAIP imagery (USFS 2009). The 2009 imagery is more up to date and was used more often, but the 2008 imagery was used in places where the 2009 imagery is of poor quality. All 41,139 shade inventory points were reviewed using the best available imagery. In many places vegetation categories from EVEG proved to be incorrect. These points were adjusted based on photo interpretation using correctly identified near-by polygons as a guide for estimating tree heights and crown densities.

Potential Vegetation and Natural Stream Shade - TMDL Methods

The Klamath TMDL develop shade curves using the Shade-a-lator model and the vegetation attributes for the mature height and density of different tree species (NCRWQCB 2010b). The shade predicted by the curves represents the stream shade expected under late-seral conditions for a given vegetation type, and a given channel width and aspect. The curves were adopted into the TMDL as numeric targets to meet the load allocation for stream temperature. However, late-seral shade conditions are not expected to occur on every stream. The TMDLs allow an adjustment to the targets based on site-specific conditions and natural factors that affect site-potential shade such as geologic or soil conditions. There is also an allowance for natural disturbances such as floods, wind throw, disease, landslides, and fire that can reduce the site-specific stream shade. The TMDL provides no method to make these adjustments other than to reduce stream shade by 10%. The Forest Service consulted with the North Coast Water Board to develop the following method.

Potential Vegetation and Natural Stream Shade – Site Specific Methods

A site-specific target for potential shade that accounts for natural factors can be estimated using the vegetation and stream shade that would be present in the absence of management. The adjusted site-potential shade at each inventory point is determined as follows:

1. At sites where the existing vegetation lacks signs of human-caused alteration, the existing vegetation and stream shade is a product of spatial variation in site factors such as soils and precipitation, and temporal variation in natural disturbances such as fire, windthrow, disease, and earth movements. The existing shade at these sites is equal to the natural shade and conditions are attaining the TMDL shade targets for potential shade.
2. At sites where the existing vegetation shows signs of significant human disturbance, the potential shade can be estimated using the shade in nearby stream reaches that lack signs of human disturbance. The degree of shade alteration is estimated by comparing the existing shade to the potential shade in the nearby reach.

Evaluation of Human Disturbance and Altered Channels

All points were evaluated for shade loss using air photo interpretation. The current stream shade at each point was interpreted as either unaltered with no visible shade loss, natural shade loss (wildfire or natural debris scour), human caused, or possibly human caused. Disturbance is identified as human-caused where there is a direct or indirect loss of shade due to human influence, such as debris flows that originate in the vicinity of a road-stream crossing, harvest units, skid trails, roads, or mine tailings. Disturbance is identified as possibly human-caused where both natural and human-caused sources are present and the photo evidence is not clear.

The altered channels mapped for the 1997 flood report (de la Fuente 1998) were re-examined to identify the land use in the area of the disturbance, and the effect of the channel alteration on stream shade. Although the 1998 report mapped debris flows resulting from the flood, it did not evaluate their source. Also, the 1998 report did not map all areas of the Forest and there are gaps in the altered channel layer. To fill in the gaps, altered channels were mapped on 1999 color resource photography (scale 1:16,000). Criteria for mapping altered channels are any one of the following: a) the channel bed exhibits an unusual color or texture relative to similar adjacent channels (usually lighter), which may be caused by recent bed mobilization, scour, or deposition; or b) the channel corridor appears to have lost a considerable amount of vegetation in 0-3 years prior to the date of the air photos. Altered channels were digitized and attributes applied to all segments. These features were then intersected with GIS coverages for roads, timber harvest, and other management to assess their proximity to management activities. Altered channels within 1000 ft. of any management were recorded as human-caused, although the actual cause was not investigated on the ground. Altered channels mapped from the 1999 photos were then overlaid on the shade inventory points and stream shade evaluated using the current vegetation and the Shade-a-lator. Stream shade was not evaluated for altered channels located on intermittent streams, the main stem Klamath, or on private lands. Some of the channels mapped as altered do not show a loss of stream shade. Overall, there is more length of altered channels than there is loss of stream shade for many watersheds.

RESULTS

Stream shade was evaluated at the watershed scale by averaging all of the shade values in each watershed. Two sets of watersheds were evaluated including the monitoring watersheds in the KNF Monitoring Plan (Tables 3, 4, 5, 6), and the HUC 12 sub-watersheds from the National Watershed Boundary Dataset (Appendix A). Each set of watersheds has advantages and disadvantages. The watersheds in the KNF Monitoring Plan are true watersheds, but they are limited to tributary streams and do not include the main channel of the Salmon and Scott Rivers. The HUC 12 watersheds are not true watersheds in that they do not drain to a single point, but they include the main channel of the Salmon and Scott Rivers. The results reported below are for the monitoring watersheds unless otherwise noted.

A comparison of the existing shade with the potential shade shows that human activities have reduced shade in 44 of the 89 watersheds on the Forest (Tables 3 to 6). The maximum reduction is 8.2%, with 12 watersheds having a reduction of greater than 1% (Figure 1). Another 12 watersheds have a decrease of less than 0.1% (Tables 3 to 6). These numbers include sites categorized as human-caused plus those in the possibly human-caused category. The actual reduction due to human causes is less because some of the sites in the possibly human-caused category are caused by natural events. The most common mechanism for human-caused reduction in stream shade and channel alteration is debris flows triggered at roads during floods, such as in 1997. Other sources identified in air photos include hydraulic mined areas, roads located in riparian reserves, and timber harvest.

Only 2 watersheds on the Forest meet the shade targets in the TMDL shade curves. Both of the watersheds that met the curves are heavily managed (Middle Horse and Mill-Scott Creeks). The 87 watersheds that do not meet the curve include 20 reference streams, many of which are located in wilderness areas.

In the Scott and Salmon Rivers, the TMDL targets are expressed as the average shade for all watersheds in the sub-basin. The average shade in all watersheds of the Salmon River sub-basin is 84 percent (Table B1). This is well above the basin-wide TMDL load allocation of 69.7%. In the Scott River the average shade in all watersheds is higher than the TMDL targets (Figure 2). It should be noted that our data is limited to Forest Service land while the TMDL target is for all ownerships.

CONCLUSIONS

Our analysis identified which streams on the Klamath National Forest are attaining the site-potential condition for natural stream shade, and which streams have reduced shade due to human-caused disturbances. The existing shade is attaining the natural site-potential shade in 45 watersheds. These watersheds have no visible evidence of management-related shade loss. Because site-potential shade is the temperature load allocation for the Klamath, Scott, Salmon, and Shasta TMDLs, these watersheds should be considered attaining the water quality objective for temperature.

A total of 44 watersheds have human-caused shade reductions below the site-potential shade. None of these watersheds meet the Klamath TMDL load allocation for site-potential effective shade. However, stream temperatures in some of these watersheds may be cold enough to support beneficial uses and meet the temperature objective of the Basin Plan even though they do not meet the TMDL shade target. If temperatures are sufficiently low to fully support beneficial uses, and haven't been increased by 5 F^{o} or more, the waterbody is meeting the objective (NCRWQCB 2007). See the steam temperature report for a list of steams that meet the temperature objective.

In watersheds where stream shade has been reduced, the cause of the reduced shade should be interpreted with caution. Although we have identified shade loss due to human activities, the actual cause was not investigated on the ground. Shade loss is categorized as human-caused simply if it is located within 1000 feet of managed areas. Some of these sites are actually natural-caused but were counted as human-caused due to their proximity to a management activity. Likewise, human-caused shade loss that is too small to detect from air photos may have been missed.

Our data shows that the average of all watersheds is attaining the Salmon and Scott Rivers TMDL targets for basin-wide average shade even though some individual watersheds are not meeting the site-potential shade. The shade targets in the Salmon and Scott River TMDLs are expressed as an average of all watersheds in the sub-basin. In the Salmon River, the basin-wide target for steam shade is 69.7%. Our data shows that the average shade in all watersheds of the Salmon River is 84%, indicating that the TMDL target is attained at the basin scale. In the Scott River, our data shows that the average shade of all watersheds is higher than the targets for each shade class in the TMDL.

The stream shade predicted by the shade curves in the Klamath TMDL is not attainable in most streams on the Klamath National Forest. Only 2 out of 87 watersheds met the shade curves values and both of these are heavily managed. None of the wilderness streams on the Forest met the shade curves. The shade predicted by the TMDL curves are too high because they are based on late-seral vegetation and do not account for local variability in site factors or natural disturbances. The curves should only be applied at sites that have no history of natural disturbance, and where the local site productivity is capable of producing the mature tree heights and densities assumed by the curves.

Opportunities to actively restore stream shade may be limited because most of the shade reduction is related to debris flows triggered by road failures. The most feasible restoration approach may be to prevent future road failures and then passively let the vegetation grow back. There may be opportunities to actively re-vegetate mined areas. However due to the Forest-wide scale of this assessment, we did not attempt to identify restoration potential at the site scale.

Table 3. Salmon River stream shade. Forest Service lands only.

Watershed Name	Managed or Reference	Stream Length Assessed (% of total)	Existing Shade (watershed average %)	Potential from Air Photos: Potential Shade (watershed average %)	Potential from Air Photos: Existing % difference from potential	Potential from Air Photos: Stream length with existing shade less than potential (km)	Potential from Shade Curves: Potential Shade (watershed average %)	Potential from Shade Curves: Existing % difference from potential	Potential from Shade Curves: Stream length with existing shade less than potential (km)
Watersheds with less shade than potential									
Eddy	Managed	100.0	93.5	95.9	-2.5	2.1	96.6	-3.2	8.1
USF Salmon1	Managed	100.0	85.1	86.6	-1.5	9.0	91.6	-6.5	84.3
USF Salmon2	Reference	100.0	85.6	87.2	-1.5	5.5	92.0	-6.3	67.1
Methodist	Managed	100.0	92.4	93.5	-1.1	0.7	95.7	-3.3	14.3
S Russian	Managed	100.0	89.3	89.8	-0.5	2.4	95.2	-5.9	29.8
Whites	Managed	100.0	95.0	95.4	-0.4	0.8	95.2	-0.2	9.8
Crawford	Managed	100.0	93.9	94.2	-0.4	0.9	94.4	-0.6	8.4
Little North Fork	Managed	100.0	91.1	91.2	-0.1	1.5	95.0	-3.9	44.4
Knownothing	Managed	100.0	91.9	92.1	-0.1	0.7	95.5	-3.5	29.5
N Russian	Managed	100.0	87.8	87.9	-0.1	0.2	93.7	-5.9	29.7
EF SF Salmon1	Managed	100.0	90.0	90.1	-0.1	1.2	93.3	-3.3	70.5
EF SF Salmon2	Managed	100.0	89.7	89.8	-0.1	1.0	93.8	-4.0	40.1
Shadow	Managed	100.0	96.3	96.4	-0.1	0.1	96.4	-0.1	4.9
Watersheds with shade at potential									
Matthews	Managed	100.0	95.3	95.4	0.0	0.2	96.0	-0.6	4.4
Black Bear	Managed	100.0	89.7	89.7	0.0	0.0	93.5	-3.8	12.4
Crapo	Managed	100.0	79.6	79.6	0.0	0.0	93.8	-14.2	25.7
Nordheimer	Managed	100.0	87.4	87.4	0.0	0.0	93.1	-5.7	36.0
NF Salmon3	Reference	100.0	90.0	90.0	0.0	0.0	94.2	-4.2	63.0
NF Salmon5	Reference	100.0	91.2	91.2	0.0	0.0	95.2	-4.1	19.7
NF Wooley	Reference	100.0	90.8	90.8	0.0	0.0	94.1	-3.3	37.4
Plummer	Reference	100.0	88.9	88.9	0.0	0.0	94.3	-5.4	18.1
RH NF Salmon	Reference	100.0	90.3	90.3	0.0	0.0	95.3	-5.0	27.2
Rush Creek	Reference	100.0	89.6	89.6	0.0	0.0	93.2	-3.7	15.5
St. Clair	Managed	100.0	94.1	94.1	0.0	0.0	95.9	-1.8	10.6
Taylor	Managed	100.0	91.9	91.9	0.0	0.0	93.9	-2.0	20.4
Uncles	Reference	100.0	95.1	95.1	0.0	0.0	96.7	-1.6	7.6
Wooley2	Reference	100.0	90.7	90.0	0.0	0.0	94.4	-3.7	171.3
Wooley3	Reference	100.0	92.0	92.0	0.0	0.0	94.9	-3.0	45.3

Table 4. Scott River stream shade and altered channels on Forest Service lands.

Watershed Name	Managed or Reference	Stream Length Assessed (% of total)	Existing Shade (watershed average %)	Potential from Air Photos: Potential Shade (watershed average %)	Potential from Air Photos: Existing % difference from potential	Potential from Air Photos: Stream length with existing shade less than potential (km)	Potential from Shade Curves: Potential Shade (watershed average %)	Potential from Shade Curves: Existing % difference from potential	Potential from Shade Curves: Stream length with existing shade less than potential (km)
Watersheds with less shade than potential									
Tompkins	Managed	100.0	90.3	92.2	-1.9	5.8	95.5	-5.2	25.0
Middle	Managed	100.0	90.5	91.6	-1.1	0.5	95.9	-5.4	8.9
Mill/Scott	Managed	60.9	96.6	96.8	-0.1	0.2	96.2	0.4	6.0
Canyon Scott1	Managed	100.0	83.9	83.9	-0.1	0.1	87.9	-4.1	29.4
Watersheds with shade at potential									
Boulder	Managed	78.2	85.1	85.1	0.0	0.0	89.8	-4.7	19.8
Canyon Scott 2	Reference	100.0	87.1	87.1	0.0	0.0	91.0	-4.0	9.2
French	Managed	54.5	91.1	91.1	0.0	0.0	96.8	-5.7	22.7
Grouse	Managed	50.7	89.6	89.6	0.0	0.0	95.0	-5.4	8.8
Kelsey	Managed	97.8	89.3	89.3	0.0	0.0	93.6	-4.4	22.8
Kidder	Managed	59.1	87.6	87.6	0.0	0.0	93.7	-6.1	12.4
Mill/Etna	Reference	100.0	93.2	93.2	0.0	0.0	96.5	-3.3	14.6
SF Scott Boulder	Managed	78.7	89.1	89.1	0.0	0.0	93.7	-4.5	32.9
Shackleford	Managed	66.6	75.3	75.3	0.0	0.0	81.6	-6.3	18.6
SF Scott	Managed	96.4	85.8	85.8	0.0	0.0	91.9	-6.2	10.0

Table 5. Lower Mid-Klamath River stream shade. Forest Service lands only.

Watershed Name	Managed or Reference	Stream Length Assessed (% of total)	Existing Shade (watershed average %)	Potential from Air Photos: Potential Shade (watershed average %)	Potential from Air Photos: Existing % difference from potential	Potential from Air Photos: Stream length with existing shade less than potential (km)	Potential from Shade Curves: Potential Shade (watershed average %)	Potential from Shade Curves: Existing % difference from potential	Potential from Shade Curves: Stream length with existing shade less than potential (km)
Watersheds with less shade than potential									
Cade	Managed	98.4	92.6	96.8	-4.1	3.2	94.8	-2.1	3.9
Ukonom	Managed	100.0	85.9	87.4	-1.5	2.9	93.8	-7.9	49.0
Indian	Managed	96.1	91.5	92.4	-1.0	6.3	95.3	-3.8	62.8
Oak Flat	Managed	100.0	95.5	96.4	-0.9	0.3	95.9	-0.4	7.1
Doolittle	Managed	95.4	95.2	96.1	-0.8	2.0	97.2	-2.0	11.4
Indian Creek	Managed	92.8	87.6	88.4	-0.8	10.8	93.8	-6.2	160.8
Thompson	Managed	96.6	95.3	96.1	-0.8	2.6	95.9	-0.6	23.0
Swillup	Managed	99.0	87.8	88.5	-0.7	0.4	91.2	-3.4	11.2
EF Indian	Managed	97.2	92.6	93.1	-0.5	1.2	94.9	-2.3	20.3
China	Managed	90.7	94.4	94.9	-0.5	2.0	97.4	-3.0	15.6
SF Clear	Managed	93.8	94.9	95.3	-0.5	1.4	96.2	-1.3	15.4
Elk2	Managed	96.9	80.1	80.5	-0.4	5.0	89.9	-9.8	134.7
EF Elk	Managed	100.0	93.9	94.2	-0.3	0.6	95.4	-1.6	21.3
Titus	Managed	97.9	91.2	91.4	-0.2	0.6	97.5	-6.3	15.5
Little Grider	Managed	97.9	96.7	96.8	-0.2	0.7	97.3	-0.6	11.4
SF Indian	Managed	96.2	82.9	83.1	-0.1	0.9	93.9	-11.0	73.8
Independence	Managed	99.1	87.5	87.6	-0.1	0.2	94.1	-6.6	24.4
Clear Creek	Managed	99.9	86.0	86.1	-0.1	1.5	93.4	-7.4	169.5
Watersheds with shade at potential									
Dillon	Managed	96.6	84.0	84.0	0.0	0.1	92.8	-8.8	132.1
Clear1	Managed	100.0	84.7	84.7	0.0	0.1	93.0	-8.3	154.1
Cedar	Reference	100.0	96.6	96.6	0.0	0.0	97.1	-0.5	1.9
Clear2	Reference	100.0	87.3	87.3	0.0	0.0	94.2	-6.8	95.0
Elk4	Reference	100.0	75.5	75.5	0.0	0.0	94.0	-18.5	48.9
Fort Goff	Reference	92.0	90.0	90.0	0.0	0.0	95.4	-5.4	12.5
King	Managed	99.0	92.6	92.6	0.0	0.0	94.8	-2.2	6.3
NF Dillon1	Managed	100.0	82.3	82.3	0.0	0.0	94.4	-12.1	68.5
NF Dillon2	Reference	100.0	78.3	78.3	0.0	0.0	93.8	-15.5	32.5
Portuguese	Reference	98.9	91.1	91.1	0.0	0.0	95.6	-4.6	11.8
Tenmile	Reference	100.0	79.7	79.7	0.0	0.0	92.7	-13.0	27.1
Twin Valley	Reference	100.0	82.1	82.1	0.0	0.0	94.7	-12.6	23.9

Table 6. Upper Klamath River stream shade. Forest Service lands only.

Watershed Name	Managed or Reference	Stream Length Assessed (% of total)	Existing Shade (watershed average %)	Potential from Air Photos			Potential from Shade Curves		
				Potential Shade (watershed average %)	Existing % difference from potential	Stream length with existing shade less than potential (km)	Potential Shade (watershed average %)	Existing % difference from potential	Stream length with existing shade less than potential (km)
Watersheds with less shade than potential									
Walker	Managed	94.5	86.2	94.4	-8.2	13.7	95.2	-9.0	20.7
Grider	Managed	99.1	90.4	92.2	-1.8	13.3	95.1	-4.7	63.3
McKinney	Managed	47.9	91.4	92.7	-1.3	0.9	95.9	-4.5	9.4
Beaver2	Managed	77.5	85.9	86.8	-0.9	8.8	90.9	-5.0	80.3
Beaver1	Managed	65.8	85.2	85.8	-0.6	8.8	90.6	-5.4	114.2
Cecil	Managed	100.0	93.5	93.7	-0.2	0.1	96.8	-3.3	7.3
Horse1	Managed	89.1	94.0	94.2	-0.2	0.3	95.2	-1.2	18.3
Seiad	Managed	99.4	84.5	84.7	-0.2	0.7	93.5	-8.9	21.7
Cottonwood	Managed	78.3	94.8	95.0	-0.1	0.3	96.7	-1.8	9.1
Watersheds with shade at potential									
Antelope	Managed	0.0	na	na	na	na	na	na	na
Butte	Managed	0.0	na	na	na	na	na	na	na
Canyon Seiad	Reference	93.7	84.7	84.7	0.0	0.0	92.2	-7.5	12.2
Humbug	Managed	84.8	88.5	88.5	0.0	0.0	95.1	-6.6	34.9
L. Shasta	Managed	29.9	62.9	62.9	0.0	0.0	69.3	-6.4	6.3
Middle Horse	Managed	27.2	95.7	95.7	0.0	0.0	95.6	0.1	0.4
Shovel	Managed	100.0	53.9	53.9	0.0	0.0	62.7	-8.7	3.4
WF Beaver	Managed	50.7	85.9	85.9	0.0	0.0	90.9	-5.0	24.1

Number of Watersheds Attaining Potential Shade

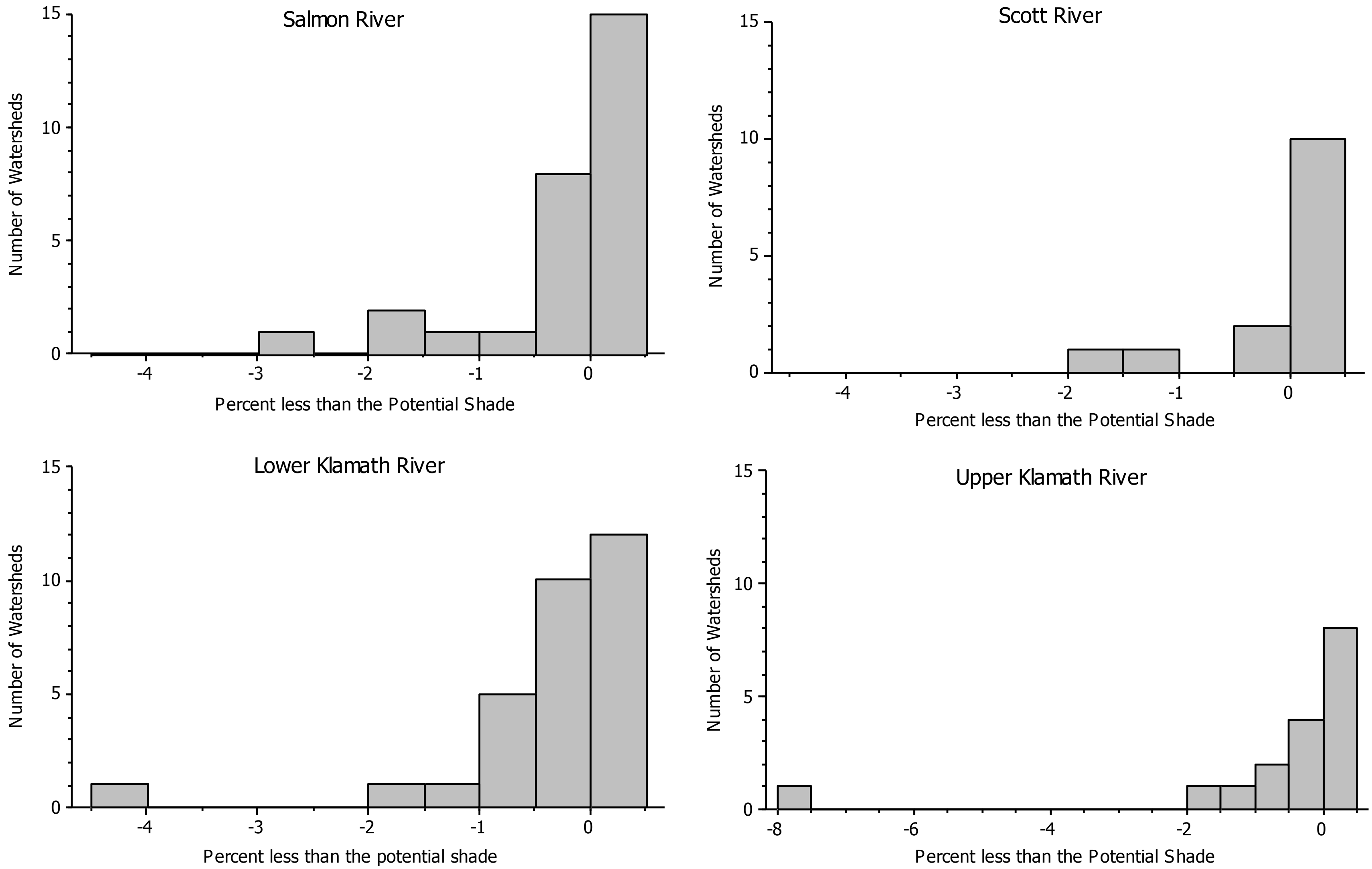

Figure 1. Frequency of watersheds attaining and not attaining potential shade conditions.

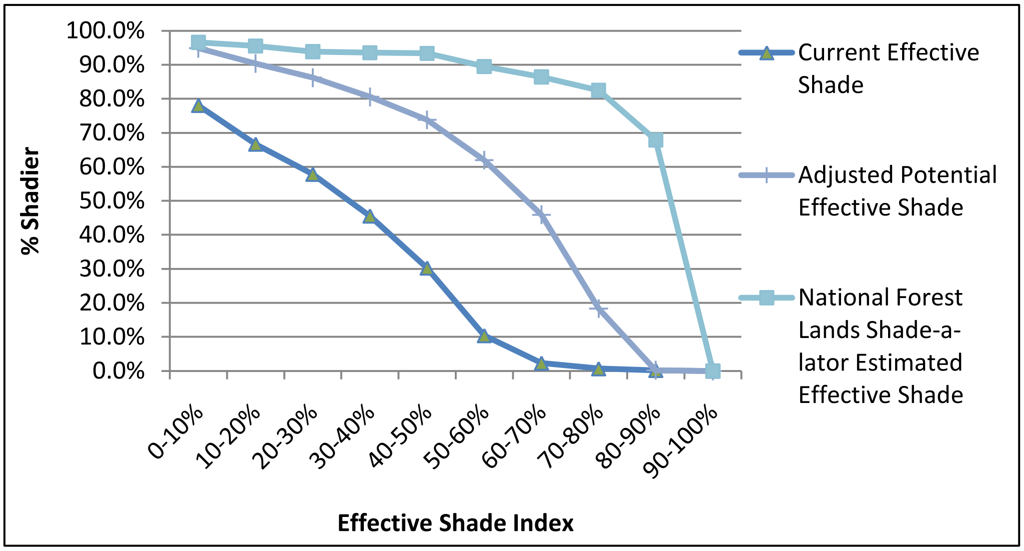

Figure2. Reproduction of Figure 4-4 from the Scott River TMDL Action Plan with an additional line for the monitoring results from Forest Service lands. The line for "current shade" is the TMDL estimate for all streams in the Scott River sub-basin. The "adjusted potential shade" is the TMDL target. The % shadier on Forest Service lands is greater than the target for all effective shade classes.

Table 7. – Modified Table 4-9 from the Scott River TMDL Action Plan with an additional column for the monitoring results from National Forest Lands. The potential vegetation column is the TMDL target. The percent shadier on Forest Service lands is greater than the target for all shade classes.

	Stream Length - Current Vegetation on all lands				Stream Length - Potential Vegetation Conditions				Stream Length – Current vegetation on National Forest System Lands			
Shade Class	miles	km	% Shadier	% of Total	miles	km	% Shadier	% of Total	miles	km	% Shadier	% of Total
0-10%	141	227	78.0	22.0	33	53	94.8	5.2	11	18	96.6	3.4
10-20%	73	117	66.6	11.4	29	46	90.4	4.5	3	6	95.5	1.1
20-30%	57	91	57.8	8.9	27	43	86.2	4.2	5	9	93.9	1.6
30-40%	78	126	45.5	12.3	36	58	80.5	5.6	1	2	93.5	0.3
40-50%	98	157	30.3	15.3	43	69	73.8	6.7	1	1	93.3	0.2
50-60%	127	204	10.4	19.8	76	122	62.0	11.9	12	20	89.5	3.9
60-70%	52	83	2.3	8.1	102	165	45.9	16.1	10	16	86.4	3.1
70-80%	11	17	0.7	1.7	176	284	18.3	27.6	13	20	82.5	3.9
80-90%	3	5	0.2	0.5	116	186	0.2	18.1	47	76	67.9	14.6
90-100%	1	2	0.0	0.2	1	2	0.0	0.2	218	352	0.0	67.9
Total	639	1028			639	1028			322	518		

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APPENDIX A – Stream Shade and Altered Channels by 6th Field HUC Watersheds

Table A1. HUC 6 watersheds – Salmon River stream shade and altered channels on Forest Service lands. Bold existing values are below the 69.7% target in the Salmon River TMDL

				Potential from Air Photos			Potential from Shade Curves		
Watershed # (HUC 6)	Watershed Name (HUC 6)	Stream Length Assessed (% of total)	Existing Shade (watershed average %)	Potential Shade (watershed average %)	Existing % difference from potential	Stream length with existing shade less than potential (km)	Potential Shade (watershed average %)	Existing % difference from potential	Stream length with existing shade less than potential (km)
Watersheds with less shade than potential									
180102100101	Big Bend Creek-South Fork Salmon River	100	84	85	-1.7	3.4	92	-7.9	45.4
180102100207	Whites Gulch-North Fork Salmon River	100	86	88	-1.6	9.9	88	-1.9	44.1
180102100104	Garden Gulch-South Fork Salmon River	100	86	88	-1.4	5.6	92	-5.2	38.9
180102100105	Crawford Creek-South Fork Salmon River	100	85	86	-1.1	3.8	87	-2.6	36.8
180102100108	Methodist Creek-South Fork Salmon River	100	73	74	-0.6	0.9	79	-5.9	34.3
180102100205	Yellow Dog Creek-North Fork Salmon River	100	86	87	-0.6	0.5	89	-2.9	20.0
180102100203	South Russian Creek	100	89	90	-0.5	2.4	95	-5.9	29.8
180102100208	Olsen Creek-North Fork Salmon River	100	**63**	63	-0.4	1.4	65	-1.9	32.6
180102100103	Main East Fork South Fork Salmon River	100	89	89	-0.1	1.2	93	-3.9	50.1
180102100404	Somes Creek-Salmon River	100	**67**	67	-0.1	0.1	68	-0.8	12.6
180102100206	Little North Fork Salmon River	100	91	91	-0.1	1.5	95	-3.9	44.4
180102100107	Knownothing Creek	100	92	92	-0.1	0.7	95	-3.5	29.5
180102100204	North Russian Creek	100	88	88	-0.1	0.2	94	-5.9	29.7
180102100106	Black Bear Creek-South Fork Salmon River	100	82	82	-0.1	0.5	85	-2.9	47.5
Watersheds with shade at potential									
180102100403	Butler Creek-Salmon River	100	**66**	66	0.0	0.0	70	-3.2	35.2
180102100402	Crapo Creek-Salmon River	100	**68**	68	0.0	0.0	79	-10.7	30.8
180102100202	Grant Creek-North Fork Salmon River	100	91	91	0.0	0.0	95	-4.1	19.7
180102100303	Hancock Creek	100	94	94	0.0	0.0	96	-2.0	20.6
180102100305	Lower Wooley Creek	100	87	87	0.0	0.0	91	-4.2	43.3
180102100304	Middle Wooley Creek	100	88	88	0.0	0.0	93	-5.0	72.1
180102100401	Nordheimer Creek	100	87	87	0.0	0.0	93	-5.7	36.0
180102100301	North Fork Wooley Creek	100	91	91	0.0	0.0	94	-3.3	37.4
180102100201	Right Hand Fork North Fork Salmon River	100	90	90	0.0	0.0	95	-5.0	27.2
180102100102	Taylor Creek	100	92	92	0.0	0.0	94	-2.0	20.4
180102100302	Upper Wooley Creek	100	92	92	0.0	0.0	95	-3.0	45.3
Sub-Basin Average % or Total Length		100	84	85	-0.34	32.1	88	-4.1	884

Table A2. HUC 6 watersheds – Scott River stream shade. Forest Service lands only

	Sixth Level Watershed Name	Stream Length Assessed (% of total)	Existing Shade (watershed average %)	Potential from Air Photos: Potential Shade (watershed average %)	Potential from Air Photos: Existing % difference from potential	Potential from Air Photos: Stream length with existing shade less than potential (km)	Potential from Shade Curves: Length of Altered Channels (km)	Potential from Shade Curves: Existing % difference from potential	Potential from Shade Curves: Stream length with existing shade less than potential (km)
Watersheds with less shade than potential									
180102080604	Tompkins Creek-Scott River	98	80	82	-1.6	6.9	86	-5.7	43.5
180102080605	Mill Creek	52	97	97	-0.1	0.2	96	0.4	6.5
180102080601	Canyon Creek	100	84	84	-0.1	0.1	88	-4.1	29.4
180102080101	Upper East Fork Scott River	37	85	85	-0.1	0.2	95	-9.7	24.7
Watersheds with shade at potential									
180102080602	Boulder Creek-Scott River	54	69	69	0.0	0.0	68	0.4	10.1
180102080205	Etna Creek	61	92	92	0.0	0.0	95	-3.2	18.7
180102080203	French Creek	41	90	90	0.0	0.0	96	-6.0	30.9
180102080501	Indian Creek	31	94	94	0.0	0.0	97	-2.7	2.8
180102080603	Kelsey Creek	98	89	89	0.0	0.0	94	-4.4	22.8
180102080402	Kidder Creek	59	88	88	0.0	0.0	94	-6.1	12.4
180102080103	Lower East Fork Scott River	47	89	89	0.0	0.0	94	-5.5	26.6
180102080303	Lower Moffett Creek	6	27	27	0.0	0.0	72	-44.3	1.3
180102080302	McAdam Creek	97	93	93	0.0	0.0	97	-4.1	5.6
180102080503	Oro Fino Creek-Scott River	43	95	95	0.0	0.0	97	-1.9	2.3
180102080401	Patterson Creek	20	92	92	0.0	0.0	98	-5.9	2.2
180102080606	Scott Bar-Scott River	62	80	80	0.0	0.0	83	-3.3	28.8
180102080502	Shackleford Creek	61	78	78	0.0	0.0	84	-5.7	21.2
180102080201	South Fork Scott River	74	88	88	0.0	0.0	92	-4.6	52.7
180102080204	Sugar Creek-Scott River	35	90	90	0.0	0.0	95	-5.1	13.5
	Sub-Basin Average % or Total Length	57	84	84	-0.10	7.4	91	-6.4	356

Table A3. HUC 6 watersheds - Lower Klamath River Stream Shade. Forest Service land only.

	Sixth Level Watershed Name	Stream Length Assessed (% of total)	Existing Shade (watershed average %)	Potential from Air Photos: Potential Shade (watershed average %)	Potential from Air Photos: Existing % difference from potential	Potential from Air Photos: Stream length with existing shade less than potential (km)	Potential from Shade Curves: Length of Altered Channels (km)	Potential from Shade Curves: Existing % difference from potential	Potential from Shade Curves: Stream length with existing shade less than potential (km)
Watersheds with less shade than potential									
180102090104	Lower Indian Creek	73	84	87	-2.3	5.8	79	5.3	18.7
180102090603	Ukonom Creek	79	86	87	-1.5	2.9	94	-7.9	49.0
180102090201	Thompson Creek	95	94	95	-1.1	6.1	96	-1.7	34.0
180102090601	Oak Flat Creek-Klamath River	94	93	94	-1.1	2.3	96	-3.4	32.6
180102090102	Upper Indian Creek	96	91	92	-1.0	6.3	95	-3.8	62.8
180102090703	Reynolds Creek-Klamath River	96	96	97	-0.9	2.3	96	-0.4	28.4
180102090203	China Creek-Klamath River	90	95	96	-0.9	5.2	97	-2.1	28.3
180102090702	Ti Creek-Klamath River	98	96	97	-0.7	4.1	96	-0.4	29.6
180102090303	Lower Elk Creek	95	78	78	-0.6	4.4	83	-4.9	66.5
180102090103	East Fork Indian Creek	97	93	93	-0.5	1.2	95	-2.3	20.3
180102090605	Swillup Creek-Klamath River	97	89	89	-0.5	0.8	94	-5.0	35.2
180102090302	East Fork Elk Creek	100	94	94	-0.3	0.6	96	-1.6	21.3
180102090403	Lower Clear Creek	94	86	86	-0.2	1.5	92	-6.1	47.4
180102090604	Titus Creek-Klamath River	94	92	93	-0.2	1.5	97	-4.3	36.0
180102090101	South Fork Indian Creek	96	83	83	-0.1	0.9	94	-11.0	73.8
180102090602	Independence Creek	99	87	88	-0.1	0.2	94	-6.6	24.4
180102090701	Rock Creek	99	93	94	-0.1	1.1	93	0.5	27.4
180102090202	Fort Goff Creek-Klamath River	95	91	91	-0.1	0.4	96	-4.9	27.6
180102090502	Copper Creek-Dillon Creek	94	85	86	-0.04	0.1	91	-5.8	63.6
Watersheds with shade at potential									
180102090501	North Fork Dillon Creek	100	82	82	0.0	0.0	94	-12.1	68.5
180102090401	Ten Mile Creek	100	80	80	0.0	0.0	93	-13.0	27.1
180102090402	Upper Clear Creek	100	87	87	0.0	0.0	94	-6.8	95.0
180102090301	Upper Elk Creek	100	75	75	0.0	0.0	94	-18.5	48.9
	Sub-Basin Average % or Total Length	95	88	89	-0.53	48	93	-5.1	966

Table A4. HUC 6 watersheds - Upper Klamath River Stream Shade. Forest Service lands only.

Watershed # (HUC 6)	Watershed Name	Stream Length Assessed (% of total)	Existing Shade (watershed average %)	Potential Shade from Air Photos: Potential Shade (watershed average %)	Potential Shade from Air Photos: Existing % difference from potential	Potential Shade from Air Photos: Stream length with existing shade less than potential (km)	Potential Shade from Curves: Potential Shade (watershed average %)	Potential Shade from Curves: Existing % difference from potential	Potential Shade from Curves: Stream length with existing shade less than potential (km)
Watersheds with less shade than potential									
180102061103	Bittenbender Creek-Klamath River	93	93	95	-2.6	15.5	96	-3.8	59.4
180102061101	Grider Creek	96	91	92	-1.7	13.3	95	-4.6	66.0
180102060901	Cow Creek-Grouse Creek	92	84	85	-1.0	8.0	90	-5.8	62.6
180102061003	McKinney Creek-Klamath River	38	91	92	-0.7	0.9	96	-4.3	15.5
180102060802	Ash Creek-Klamath River	34	80	80	-0.7	1.0	84	-3.8	4.1
180102060902	Hungry Creek-Beaver Creek	54	91	92	-0.5	0.8	94	-2.6	17.7
180102061002	Little Humbug Creek-Klamath River	72	86	87	-0.5	0.2	92	-6.1	9.1
180102060601	Upper Cottonwood Creek	60	94	94	-0.2	0.5	96	-2.4	21.8
180102061004	Horse Creek	64	93	93	-0.1	0.7	95	-2.0	27.5
180102061102	Seiad Creek	89	85	85	-0.1	0.7	93	-7.9	38.4
Watersheds with shade at potential									
180102061001	Barkhouse Creek	57	92	92	0.0	0.0	91	1.6	6.0
180102060701	Bogus Creek	26	93	93	0.0	0.0	97	-3.2	6.3
180102060303	Deer Creek-Klamath River	40	72	72	0.0	0.0	85	-13.0	7.5
180102060904	Dutch Creek-Beaver Creek	43	76	76	0.0	0.0	87	-10.9	9.9
180102060602	East Fork Cottonwood Creek	15	96	96	0.0	0.0	97	-1.3	2.6
180102060803	Empire Creek-Klamath River	57	90	90	0.0	0.0	94	-4.6	18.8
180102060801	Humbug Creek	77	88	88	0.0	0.0	95	-6.7	35.2
180102061005	Kohl Creek-Klamath River	33	94	94	0.0	0.0	96	-2.1	7.2
180102060604	Lower Cottonwood Creek	8	97	97	0.0	0.0	97	-0.05	0.9
180102060603	Middle Cottonwood Creek	1	39	39	0.0	0.0	39	-0.03	0.2
180102060301	Shovel Creek	30	69	69	0.0	0.0	78	-8.7	8.1
180102070301	Upper Little Shasta River	31	68	68	0.0	0.0	76	-7.9	9.8
180102060903	West Fork Beaver Creek	51	86	86	0.0	0.0	91	-5.0	24.1
180102060703	Willow Creek	19	96	96	0.0	0.0	97	-1.3	0.5
	Sub-Basin Average % or Total Length	47	85	86	-0.34	41.6	90	-4.4	459

APPENDIX B – Quality Control and Field Verification of

Stream Shade Predicted by the Shade-a-lator Model

METHODS

Stream shade was measured in the field to verify a sub-sample of the shade values estimated by the shade-a-lator model. All inventory points in the study were stratified into 10 shade categories, and then 7 to 12 random points were measured from each category. At each sample site, stream shade was measured at 5 transects spaced 20 meters apart. The total number of measurements depends on the bankfull channel width (Table B.1). The existing shade was measured using Hemispherical Canopy Photography and the Hemiview camera system. Protocols for equipment, setup, taking photographs, and the analysis software are described in Appendix C of the Quality Assurance Project Plan (USFS 2010).

The precision of each shade indicator is determined using repeat surveys at three sites randomly selected from all sites in the survey. Crew variability is evaluated using two successive measurements by different crews at the same site. This metric represents the variability between crews due to differences in where and how measurements are made.

RESULTS

Compared to the field measurements, the shade predicted by the shade-a-lator has a large scatter (Figure B.1). The shade-o-lator tends to over predict shade at the upper end of the range, and under predict at the lower end. The mean difference between the predicted and measured shade ranges from 0.4 percent in the 70 to 80 percent shade category, to over ±17 percent in the 10 to 20 percent and 80 to 100 percent categories (Table B.2). The quality control check using repeat surveys shows a relatively small error due to measurement differences between crews (Table B.3).

There at least two potential reasons for the large discrepancy between the modeled and measured stream shade:

1. Inherent errors in the Shade-a-lator model. The Shade-a-lator may not accurately model the complex variables affecting stream shade.

2. The resolution of the available data is not adequate to detect small changes in vegetation. Input variables must be lumped into broad categories at the upper and lower ends of the range (Table 2).

Table B.1. Location of shade sample points along stream transects.

Channel Width (m)	# of sample points per transect	Location along transect (portion of bankfull width)
0 to 6	1	0.5
7 to 12	2	0.33 and 0.66
>13	3	0.25, 0.5, and 0.75

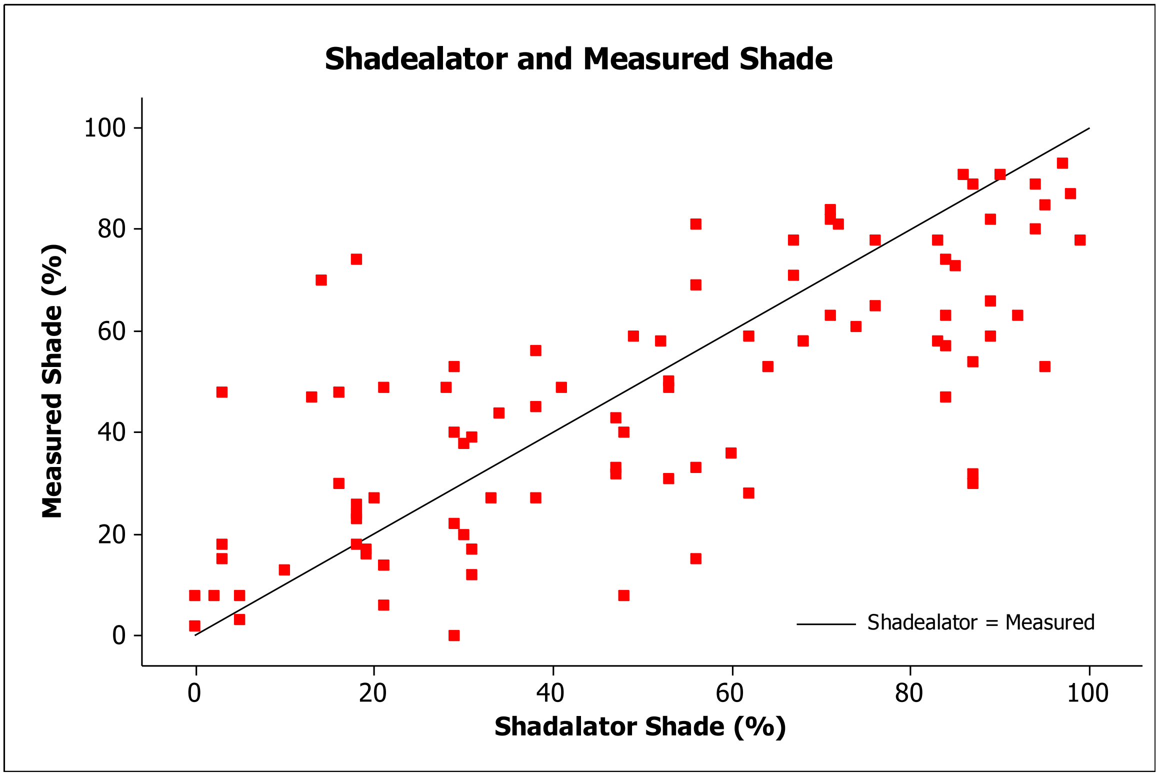

Figure B.1.

Table B.2. Difference between stream shade predicted by the shade-a-lator model and field measured shade.

Shade-a-lator Shade Group	Number of Field Samples	Average Shade-a-lator Estimated Shade	Average Field Measured Shade	Mean Difference	Standard Error of the Difference	Conclusion
90-100%	9	95.0%	79.9%	15.1%	4.5%	99% certain estimate is high
80-90%	12	85.9%	68.4%	17.5%	4.8%	99% certain estimate is high
70-80%	7	73.4%	73.5%	-0.4%	4.2%	Estimate consistent with Field Shade
60-70%	10	65.6%	54.4%	11.2%	4.3%	95% certain estimate is high
50-60%	8	54.3%	48.2%	6.1%	7.6%	Estimate consistent with Field Shade
40-50%	7	46.5%	37.8%	8.8%	6.3%	Estimate consistent with Field Shade
30-40%	10	33.4%	32.6%	0.9%	4.0%	Estimate consistent with Field Shade
20-30%	9	25.2%	27.5%	-2.3%	6.6%	Estimate consistent with Field Shade
10-20%	12	17.2%	35.0%	-17.8%	6.2%	95% certain estimate is low
0-10%	10	3.5%	15.2%	-11.7%	4.4%	95% certain estimate is low

Table B.3. Quality control check for different crews independently sampling the same sites.

Point ID	Stream Name	Crew A Shade	Crew B Shade	Difference % Shade (A – B)
29249	Lick Creek	58.6%	62.7%	-4.1
33194	Elk Creek	44.2%	48.4%	-4.2
41748	Horse Creek	80.0%	79.5%	0.5
Mean				-2.6